

Physico-Chemical And Therapeutic Characteristics Of The Thermo-Mineral Waters of Khenchela Region (Northeastern Algeria)

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Received 08 Dec 2016,
Revised 24 Jan 2017,
Accepted 28 Jan 2017

Keywords

- ✓ Thermo-mineral water;
- ✓ Therapeutic virtues;
- ✓ Thermalism;
- ✓ Physico-chemistry;
- ✓ Spas of Algeria;

Abstract

This study is carried out on three thermal stations in Khenchela region, Hammam Essalihine: two thermo-mineral springs, Hammam El Knif and Hammam Djaarir. The first two resorts have all the facilities in terms of equipment but the resort Hammam Djaarire has only one room. The aim of this study is to determine the physical, chemical and therapeutic characteristics of the thermo-mineral waters in the region of Khenchela. Thermalism in Khenchela region is an ancestral medicine using natural mineral waters for several medical utilities. The thermo-mineral waters of Khenchela region are sodium chloride nature, and they are rich of sulphates and magnesium. They fit with a total of nine therapeutic indications from the twelve known globally.

1. Introduction

Thermalism in Algeria is not a phenomenon of the contemporary era. The use of thermal waters for therapeutic purposes dates back to the dawn of time. Already the Romans had known how to "domesticate" the waters that sprang from the subsoil, certainly archaic, for lacking any scientific basis. It remains, however, that they were the first to give us the historical proof of their curative virtues. History tells us that the Romans, by inhabiting the regions of North Africa, had discovered norias of griffins [1].

Thermalism in Algeria is a priority for the development of the economic sector given the existence of a very important thermal potential to be valued, especially in the east of the country, as well as a multiform demand of the population in search of vacation, rest, relaxation, care, fitness and well-being.

Among the Algerian thermo-mineral heritage, which consists of more than 200 listed thermal springs or sources, we have chosen three thermal springs in Khenchela region. They are concerned by this work, That will make them consistent to the professional standards of the activity, to improve their standing, the quality of services and care provided and finally to position on the world market of hydrotherapy with a view to gradually integrating them into international trade channels. These are the Thermal resorts of Hammam Essalihine, Hammam El Kenif and Hammam Djaarir.

The resorts Hammam Essalihine and Hammam El Knif are equipped with all facilities for hotels, family bungalows, apartments and studios, spa and a professional support as well as hospitality and medical to answer the needs of people, visitors, families, tourists and this, in the best conditions of comfort. [2]. While the resort Hammam Djaarir is composed of a single room.

Data on characteristics of the thermo-mineral waters of Khenchela region are scarce and missing especially for despite the notable lack of data on the thermo-mineral waters; there has been no research until now on the therapeutic characteristics of the thermo-mineral waters. The few published data are very limited to Physico-chemical characteristics, and they address only the hydrological and bacteriological characteristics.

2. Experimental

2.1. Studied area

This study is carried out on three thermal spas in Khenchela region:

2.1.1. Hammam Essalihine

It is located in the municipality of El Hamma, 7 km northwest of Khenchela region, south of the Remila basin, in a mountainous depression, covering the geographically limited area by the latitudes 35° 26 '20.12 "N and 7° 05 08.46" E longitude. The altitude of the zone varies from 1079 m in the valley of the thermal site of Hammam Essalihine to 1650 m at the height of Ras Serdoun, and culminates at 1870m in the jebel Feraoun, this thermal site is made up of three springs [11].

The water spring of Hammam Essalihine is very rich in minerals; this water is so pure that it needs no filtering. It cools naturally before reaching the basins where it is continually brewed; the baths always retain the picturesque Roman pools.

The thermal complex offers all the treatments appropriate to the cures: relaxation, massage, functional rehabilitation in addition to the hydrotherapy sessions provided by a couple of physiotherapists. The baths welcoming nearly 900000 people each year, allowed other public and private reception structures to be created, such as the rest centers reserved for the Mujahedeen and the other for the postal workers [1-12].

2.1.2. Hamam El Knif

Located at 15 km northeast of Khenchela region in the municipality of Baghai, it covers the area bounded geographically by latitudes 35° 29 11.63 "N and 7° 15 08.64" E longitude. The altitude is 1016 m, was discovered in 1905 by a local shepherd. It was subsequently furnished during the French colonial period. The baths of sulphurous vapors or "Vaporium" are found inside a building perched on a rocky promontory which dominates a panorama of all beauty. In [11]. Unfortunately, rooms in place of "Sauna" for patients suffering from respiratory diseases, neurological and rheumatic fever diseases are no longer suitable for this care. The built environment has simply become obsolete. Below and in the vicinity of a wade with clear waters, other more recent constructions constituting the new spa (hot waters of the source Knif), try to satisfy Customers always more numerous but legitimately more are demanding. Its annual capacity is 40000 people. This station is recommended for the treatment of rheumatic and dermatological diseases [3-12]

2.1.3. Hammam Djaarir

Located in the municipality of Bouhmama, 60 km north-west of Khenchela, it covers the geographically limited area by latitudes 35° 16 '45 "N and 6 ° 47' 23" E longitude. Altitude is 1102 m, it is a primitive station composed of a single room.



Photography 1: Hammam Essalihine



Photography 2: Hammam El Knif.

2.2. Geology of the studied area

In the area studied, the lower Cretaceous deposited in the form of marly limestones, marl, calcareous sandstone and compact limestones. The Aptian and the Albian appear in the studied area. The Albian exists in the anticlines of the Aures; it often presents a sandy, marly and dolomitic facies. To the south of the basin, the Albian is represented on the edge of the Anticlinical of Hammam Essalihine (Djebel Aidel) which overlooks the thermal springs. The tertiary is composed of red gypsum clays and rests directly, unconformably, on the cretaceous. This formation is composed of sandstone marls and sandstones rest directly on the base conglomerate. It should be pointed out that these marine Miocene formations, often classified as "sandstone", included only a few sandstone banks embedded in a large thickness of sandstone marls. As a result, these sandstone marls appear to be very friable outcrop, constitute in reality a rock hard enough. The thickness of this marine series seems to vary from 200 to 400 m [4-5-12]. (Fig.2)



Figure 1: Spas of Khenchela region. (Northeastern Algeria.)



Figure 2: General view of Hammam El Knif and its surroundings.

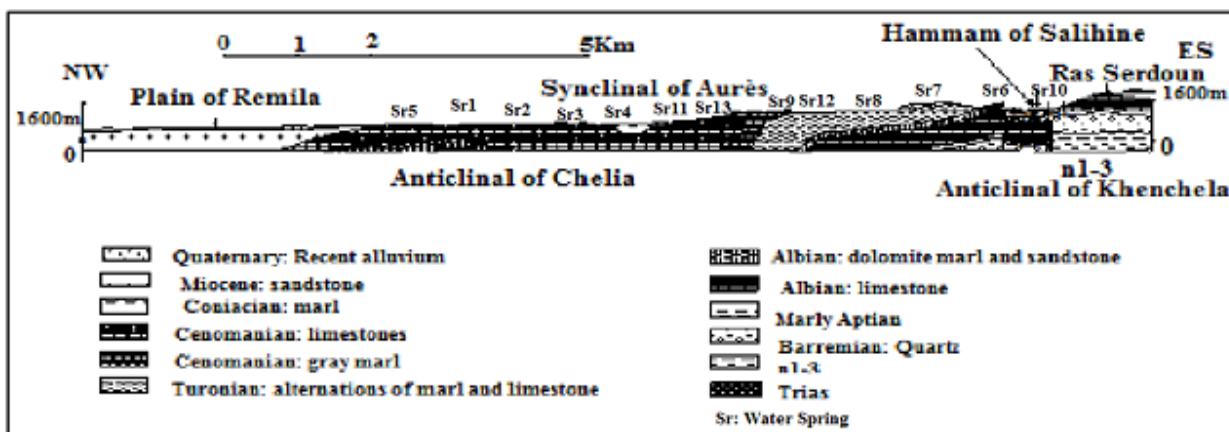


Figure 3: Geology of studied area [4] modified.

2.3. Sampling and Analytical Techniques

During the year of 2014, sampling of thermo-mineral water was carried out in clean plastic bottles of 1.5 liters capacity, rinsed several times with the water to be sampled and sealed to avoid contact with atmospheric gases [13]. The water samples were directly transported to the laboratory within a period of no more than 8 hours for chemical analysis.

The analysis of non-conservative physical parameters: temperature, pH, electrical conductivity, mineralization, was carried out *in situ* using a multi-parameter type "Consort C931, version 2.4".

The analysis of the major chemical elements was carried out in the laboratory LASPI.2.A, Ain M'lila, Algeria.

The measurement of the geographical coordinates was carried out *in situ* with a GPS, GARMIN type.

The chemical type of the waters and their origin were determined by the DIAGRAM software of the University of Avignon-France.

3. Results and Discussions

3.1. Physical parameters

3.1.1. Water temperature

The temperature of the water is influenced by the temperature of the air; it has a key role in the solubility of salts and gases. It makes it possible to differentiate between the waters that circulate at depth and those that circulate near the surface. This is one of the factors that influence the speed of chemical reactions. It is noted that these high temperatures testify to a deep origin of the waters [4] (Fig.a.4).

This thermal imbalance between the atmosphere and the aquifer indicates that the waters have a very deep origin. They are influenced by the geothermal gradient on the one hand, seismic activity, radioactive decay and endogenous chemical reactions producing energy on the other hand. Note also that the friction between the geological layers during the seismic activity produces heat that heats the water of the aquifers.

In the hypothesis of a heating of the meteoric water under the influence of the geothermal gradient, we must assume that the water slowly infiltrates to have the possibility of heating up and that it must rise quickly to avoid the loses its heat on contact with colder rocks, although in steady state these losses are small [6].

The hypothesis of the contribution of tectonic activity, currently very active, to thermal water in Khenchela, by heat generated by friction along the fault planes, which is added to the influence of the geothermal degree [6 - 10], seems to be necessary to explain temperatures above 40-45°C, because the geothermal gradient alone does not explain the height temperature of Khenchela springs, given that in the present state the waters cannot flow at depths greater than 600 or 1000 m, assuming a geothermal gradient of 4.19 °C /100m [4-6].

3.1.2. The pH

The pH is above all determined by the free carbonic acid content. However, it can also be influenced by the land use (use of ammonia fertilizers) or by natural processes (exchange of materials between plants and soil, formation of humic acids during degradation of organic matter. In addition, acid rain (H⁺) can lower the pH of groundwater in low-buffered soils because they lack carbonates [7].

The measured values indicate a basic pH. These thermo-mineral waters are characterized by the presence of hydroxide ions HO⁻ which result from the loss of an H⁺ proton by a molecule of water. An aqueous solution is considered basic when it contains more HO⁻ than pure water. This is due to the atmospheric gas exchange [7] (Fig.b.4).

3.1.3. The mineralization

The mineralization of the waters is determined by the chemical and mineralogical nature of the sediments they flew through. The thermo-mineral waters are much mineralized. They are directly related to the gypsum-saline sediments of Triassic so widespread in Algeria, this case is encountered as an example in Hammam El Salihine. To better understand the process of mineralization of thermal waters, it is necessary to represent the major elements as a function of chloride [4]. The latter is a conserved element, does not participate in water-rock interactions, characterizes the origin of the salinity of the waters and constitutes a tracer of mixture. They are all more than 600 mg/l (Fig.c4).

3.1.4. The electrical conductivity

The electrical conductivity values of thermal mineral waters of Khenchela region indicate a high mineralization. They are all above 1650µS/cm, which reflect the high solubility of the salts at high temperatures. These values indicate that the thermal waters are mineralized and have crossed the Triassic gypso salt terrains and are linked to the high solubility of the salts (NaCl, CaSO₄.2H₂O⁺, CaSO₄. and Na²⁺ SOH⁻) (Fig.d.4).

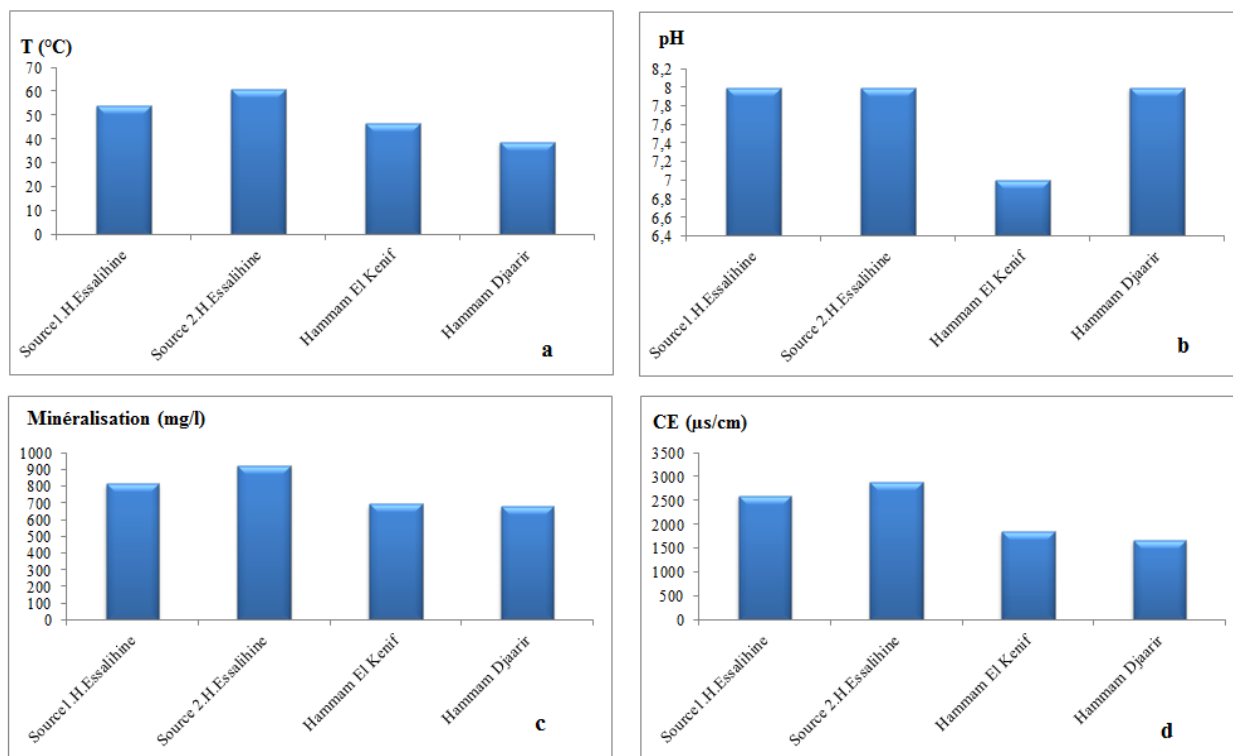


Figure 4: Physical parameters of thermo-mineral springs of Khenchela region.

3.1. Chemical parameters

The chemical analysis of the major ions allowed us to distinguish the different concentrations of these elements. (Fig.5).

The graphical representation of the major elements on the Piper diagram revealed the same chemical type chloride sodium for all studied thermo-mineral waters (Fig. 6).

According to Berkaloff's graphic representation, it is remarked that thermo-mineral waters do not have the same origin since their straight lines intersect with one another. Each water source crosses a different path from the other (Fig.7).

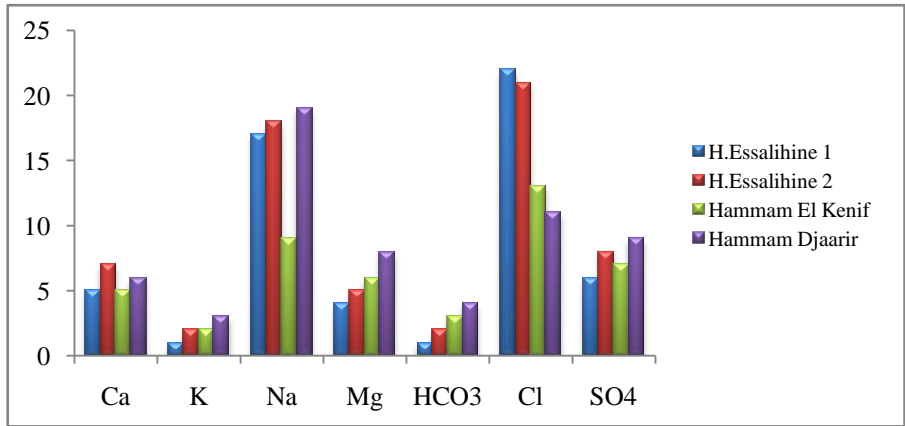


Figure 5: Concentrations of the major chemical elements of the thermo-mineral waters of Khenchela region (May 2014).

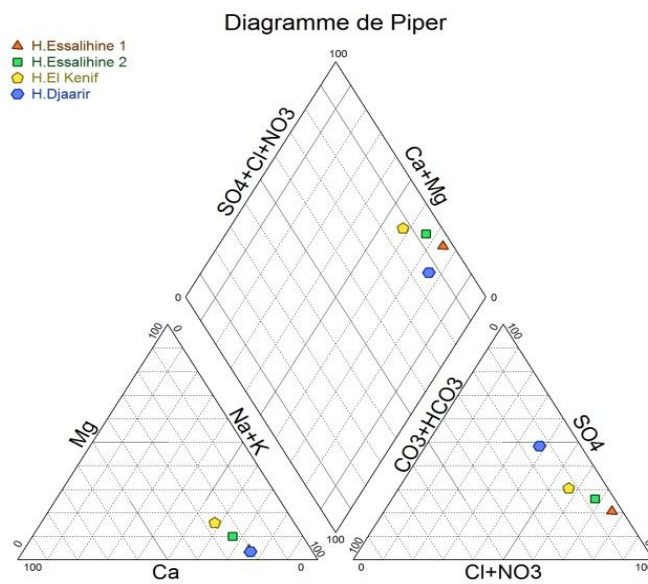


Figure 6: Graphical representation of Piper.

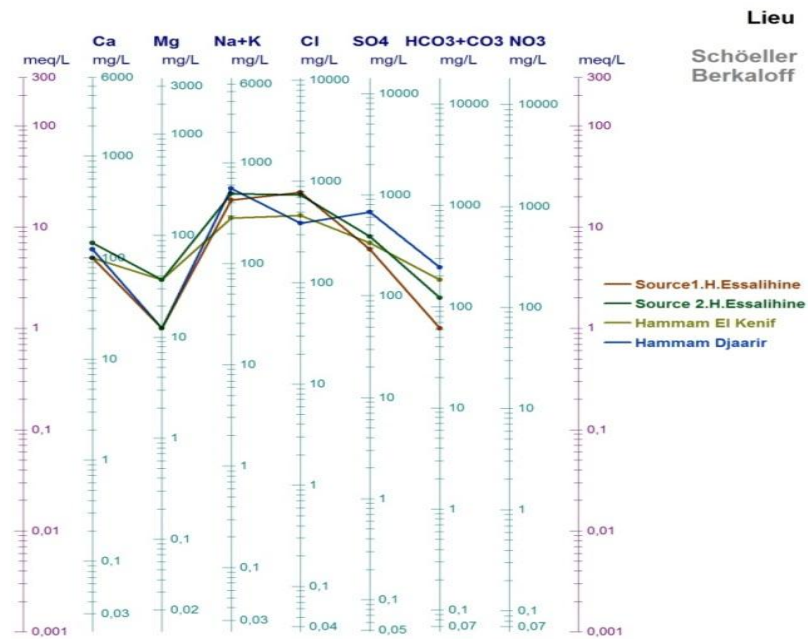


Figure 7: Graphical representation of Berkaloff.

3.2. The Cremotherapy: The therapeutic virtues of the thermo-mineral waters of Khenchela region

Thermalism is the therapeutic use of the properties of certain thermal mineral waters to heal or relieve people suffering from various ailments and pathology. All medical, sanitary, administrative, social and hospital facilities are mobilized for the use of mineral waters, thermal gases and thermal mud for therapeutic purposes: thermal therapy or cremotherapy. Thermal medicine is natural. It is a gentle, complementary medicine and is an alternative to other medical care [8-9].

The thermal mineral waters of the Khenchela region are chloride-sodic, in which there is a high concentration of chloride and sodium, generally come from salt rocks deposits. They have a stimulating effect on growth and are indicated in the treatment of developmental disorders and enuresis.

They are also rich in sulphates (high in sulfur). They are indicated for the affections of the kidney and in some metabolic diseases. They are also recommended for the treatment of eczema and burn-related sequelae. [10]

The presence of significant concentrations of magnesium in these waters renders them with significant power and useful in the treatment of metabolic and digestive diseases. In parallel, this trace element magnesium boasts also sedative virtues, favoring the sleep. Generally speaking, magnesium improves the tonicity of muscle fibers, sovereign effects in the treatment of phlebological disorders, because the muscles have a visible action on venous return. [10].

Table 1: The orientations of thermalism and the most frequent indications. In [10].

Orientation	Frequently asked questions
Rheumatology and trauma Osteoarticular	Chronic rheumatism Arthrosis Tendonitis Lower Back Pain Rachis operated and imperfectly relieving Sequelae of osteo - articular trauma
Respiratory tract and ENT disorders (Children from 3 years)	Rhinitis Otitis, serous Sinusitis Laryngitis Asthma Chronic bronchitis Dilation of the bronchi
Gynecology	Pelvic Algies
Phlebology	Venous insufficiency Sequelae of phlebitis Cicatrisation of venous ulcers Decreased lymphedema
Cardiovascular diseases	Arteritis of the lower limbs High Blood Pressure Chronic Angina Raynaud's Syndrome

Conclusion

The mineralization of thermal waters is determined by the chemical and mineralogical nature of the sediments they flew through. The most mineralized thermal springs are directly related to the gypsum-saline sediments of the Triassic so widespread in Algeria [2].

Thermalism in Khenchela region presents a very important potential, in terms of therapy. The thermal resorts Hammam Essalihine, Hammam El Kenif and Hammam Djaarir are characterized by sodium chloride waters rich in sulphates and magnesium. They respond to nine of total therapeutic indications out of twelve globally, this could put the quality of these waters and their medical interest in different pathologies.

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(2017) ; <http://www.jmaterenvironsci.com>